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ALBERTA. DEPT. OF THE ENVIRONMENT. STANDARDS AND APPROVALS DIVISION

AIR POLLUTION CONTROL AND THE DEVELOPMENT OF THE ATHABASCA OIL SANDS

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AIR POLLUTION CONTROL AND THE DEVELOPMENT OF THE ATHABASCA OIL SANDS

by

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STANDARDS AND APPROVALS DIVISION

Edmonton, Alberta

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(1) Introduction

One oil extraction plant has been operating in the Athabasca Oil Sands for several years, construction has just commenced on a second plant, approval in principle has been given for a third plant, and application has just recently been made for a fourth plant. The current energy situation will inevitably increase this type of rapid development and, consequently, the Alberta Department of the Environment is faced with the monumental task of ensuring that this industrial growth will have a minimal effect on the surrounding environment.

Under The Clean Air Act, some of the primary concerns which the Department has regarding the oil sands industry are the adequate control and monitoring of atmospheric emissions and the effects of local topography and meteorology on the assimilative capacity for atmospheric pollutant dispersion.

(2) Control of Air Contaminants

The main air contaminants, which are common to oil sands plants and which are considered to be potentially detrimental to the environment, are sulphur-bearing compounds (mainly sulphur dioxide), oxides of nitrogen, and particulates (including heavy metals). Other contaminants which are somewhat less critical are hydrocarbons, odorous materials, carbon monoxide and smoke - the latter item being considered as an aesthetic problem.

To illustrate the allowable ambient concentrations of some of these contaminants, attached is Table I, which summarizes the appropriate section of The Clean Air (Maximum Levels) Regulations.

Although the total control of airborne industrial pollutants is the ultimate objective, present-day technology unfortunately does not permit us to achieve this goal and it will probably be some time before we eventually accomplish

this great feat. Control at the source is the preferrable technique to protect the environment from contaminant effects but on a realistic basis, we must concede that some pollutants will be released into the atmosphere.

To optimize the dispersion of air contaminants from oil sands plants, the Department now requires that contaminants such as sulphur-bearing compounds, oxides of nitrogen and particulates be discharged to the atmosphere through one main stack. The main feed to the stack would be the tail gas from the utility plant and the sulphur plant. By combining these primary atmospheric effluents in this manner, the plants will take full advantage of the cumulative plume rise effect, and the in-stack concentrations and flow rates will be more effectively monitored.

(A) Sulphur Dioxide

The damaging effects of low concentrations of sulphur dioxide on vegetation are well known and consequently, the control of this contaminant from oil sands plants is of the utmost importance. Due to the chemical composition of the bituminous sands, the refining process unavoidably results in the production of the sulphur-bearing compounds as by-products.

The sulphur plant will process the various sour streams to convert hydrogen sulphide to elemental sulphur; however, even with the highest recovery rates achievable with present-day technology, some sulphur dioxide will be discharged to the atmosphere from this source. For those plants using solid fuel to supply energy demands, the utility plant will be the largest source of sulphur dioxide emissions, since petroleum coke, on the average, contains 5 to 6 percent by weight sulphur. The preferrable technique to control sulphur dioxide emissions would be flue gas desulphurization or sulphur removal from the feed coke.

The design criteria for the calculated ground level concentration of sulphur dioxide was stated in the Department's "Syncrude Criteria" as follows:

A critical and important assumption made in the development of sulphur dioxide emission allowables was that five plants (design and capacity of Syncrude) would be built in a line spaced approximately five miles apart. The constraint would therefore be the cumulative effect of overlapping stack plumes from the five plants and the process and stack designs must be such that the calculated ground level concentration does not exceed 0.20 ppm. With this restriction, the individual plants must base their designs so that the calculated ground level concentration does not exceed 0.06 ppm, with respect to sulphur dioxide.

Compliance with this criteria would be determined by the use of the Pasquill plume dispersion model with the Bosanquet-Carey-Halton plume rise formula.

In-stack sulphur dioxide concentrations will be restricted to levels which correspond with the above point of impingement criteria but some operational flexibility will be allowed to account for process upsets and equipment malfunctions. Another associated design and operational constraint will be the requirement of meeting minimum sulphur recovery efficiencies which are a function of the rated inlet capacity to the sulphur plant. Table II outlines the sulphur recovery guidelines as they pertain to oil sands plants. These are only general guidelines based on favourable acid gas quality and each plant will be reviewed on an individual basis.

To further regulate the emission of sulphur dioxide to the atmosphere, two design features are recommended:

(1) the maximum release of sulphur dioxide from an oil sands plant shall not exceed a level which corresponds to the ratio of 1.0

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long ton of sulphur dioxide per day for every 1000 barrels of raw bitumen feed stock to the upgrading process, and,

(2) the sulphur recovery plant shall include a duplicate standby recovery train which is kept in an idling condition for instantaneous commissioning should the need arise.

Implementation of these types of constraints will be determined again on an individual plant basis; however, the Department is very emphatic in its policy that the best practicable technology be incorporated into the plant design to control and reduce pollutant discharges.

(B) Oxides of Nitrogen

In general, the quantity of oxides of nitrogen being released from oil sands plants is much less than that of sulphur dioxide but nonetheless the damaging effects of nitrogen dioxide are quite similar to sulphur dioxide. Consequently, the design criteria for oxides of nitrogen (assuming complete conversion of NO_x to NO_2) is that the maximum calculated ground level concentration shall not exceed 0.06 ppm expressed as nitrogen dioxide. This is the case even though the allowable ambient concentration is based on a one-hour average time period.

Since the production of oxides of nitrogen is directly related to the many combustion processes in an oil sands plant, the control of such contaminants is more difficult. However, through the use of more efficient combustion equipment and improved process control techniques the formation of oxides of nitrogen can be minimized.

(C) Particulates

The control of particulates is an absolute necessity where a plant is burning by-product coke as fuel for the utility plant. For those plants which choose

to combust solid coke in the boilers, the particulate emissions must be controlled to a level not to exceed 0.20 pounds per 1000 pounds of flue gas adjusted to 50 percent excess air.

Suspended particles in the atmosphere can be associated with restricted visibility in localized areas but more important than this, particulate matter has been responsible for severe health effects. Some particles from combustion processes contain substances such as benzo-a-pyrene and others which are known to be carcinogenic. Synergistic reactions involving airborne particles and gaseous contaminants such as sulphur dioxide can and do occur under certain conditions with potential damage to human health.

Another concern in discussing the topic of coke combustion is the possibility of toxic effects from heavy metals contained in the feed coke and released to the atmosphere along with portions of the fly ash. Although the potential effects of high concentrations of heavy metals are quite well documented, the metals characteristic to the oil sands are relatively unknown at this time. Thus, the industry will be responsible for a sampling and analysis program to acquire a heavy metals inventory and this data will subsequently determine where future control might be necessary.

For those plants burning solid fuel, pollution abatement equipment, probably in the form of electrostatic precipitators, will be an integral part of the utility plant to enable compliance with the particulate emission regulations and for the protection of the surrounding environment.

(D) Other Contaminant Emissions

(i) Hydrocarbons

In large industrial developments which have the primary objective of hydrocarbon recovery, the potential for hydrocarbon losses to the atmosphere is obviously very high. Unless adequate controlling measures are taken at the design stage, the oil sands area could quite readily develop the necessary ingredients for the formation of photochemical smog episodes. This would mean that the proper ambient concentrations of hydrocarbons and oxides of nitrogen in the presence of sunlight and under atmospheric stagnation conditions which are common to the Fort McMurray area could result in smog formation.

In addition to potential smog formation, hydrocarbons are perhaps better known as odorous materials and the nuisance factor is common to the hydrocarbon processing industry. Considering the possible effects of atmospheric hydrocarbons, the importance of controlling these emissions cannot be over-emphasized.

The largest sources of atmospheric hydrocarbons are breathing losses from storage tanks and a general design criteria requires that all tankage be designed and equipped for vapor and gaseous emission control as follows:

(a) all tanks that are over 50 feet in diameter holding stocks with a vapor pressure of 3 to 12 pounds per square inch absolute shall be provided with a floating roof designed with a closure seal or seals to close the space between the roof edge and the tank wall, and,

(b) all stocks with a vapor pressure greater than 12 pounds per square inch absolute shall be stored in closed vessels or pressure spheres.

Further preventative systems such as flare stacks will be required to minimize the quantity of unburned hydrocarbons released to the atmosphere. These flares

will be designed for smokeless burning and they must be equipped with a continuously burning pilot and automatic flame ignitor.

(ii) Odorous Emissions

Inevitably, most large industries have a characteristic odor emanating from the various processing areas and unfortunately, an oil sands plant is no exception to this rule. Materials such as hydrocarbons, mercaptans, ammonia, hydrogen sulphide, etc., are common causes of industrial odor problems. At concentrations detectable by the olfactory senses these materials are not considered to be an environmental hazard but rather they are more of a nuisance.

Through improved processing techniques for the handling of odorous materials and by observing strict purging and cleaning procedures during equipment maintenance, the emission of objectionable odors can usually be confined at the potential source. Should offensive odors be detected frequently in the vicinity of a plant, the company would be required to undertake a survey to determine what is causing the problem and what steps have to be taken to eliminate the emissions.

(iii) Carbon Monoxide

The formation of carbon monoxide is a result of the incomplete combustion of any carbonaceous material. With the many process heaters and combustion processes common to an oil sands plant, the potential for carbon monoxide emissions is extremely high. However, by the efficient operation of combustion processes, the level of carbon monoxide in the flue gases can be controlled to essentially zero.

Carbon monoxide is potentially fatal to humans because it reduces the oxygen carrying capacity of the blood. The primary source of atmospheric carbon monoxide is the automobile and, in comparison, industrial sources contribute only a very small percentage.

(iv) Smoke

Under normal processing conditions, smoke emissions should be non-existant. With modern technology, flaring systems can be designed for smokeless burning, but under severe emergency conditions the incomplete combustion of vented process gases does occur.

If flaring operations or burn pit systems result in smoke emissions, the intensity, duration and frequency of the visible emission shall not exceed the limitations specified in The Clean Air (Maximum Levels) Regulations.

(3) In-Stack and Ambient Monitoring Requirements

The only absolute method of determining the efficiency or performance of the pollution control facilities is to continuously monitor the stack effluent for specific contaminants. Likewise the best technique to determine ambient contaminant concentrations at the point of impingement is to continuously monitor the area in the vicinity of a plant.

The field of air pollution monitoring instrumentation has improved very significantly in recent years to a point now where reliable equipment and operational expertise is fairly accessible for most industrial applications. In view of this type of technological advancement, industry must now accept full responsibility for the quality and quantity of atmospheric emissions and continuous in-stack and ambient monitoring are the means by which this

objective will be realized.

Each oil sands plant shall provide a monitoring program designed to assess plant operations and their associated air contaminant emission characteristics. The following information shall be obtained on a continuous basis:

(a) The bolometer readings and the corresponding estimated particulate concentration and mass emission rate in the main stack flue gas;

(b) the exit temperature of the gases from the main stack; and

(c) the concentration and volume flow rate of sulphur dioxide in the gases being discharged from the main stack.

Stack surveys of the main stack flue gases are to be conducted at a frequency specified in Attachment I with the following determinations being made:

(a) the concentration of sulphur dioxide, oxides of nitrogen and particulates and the corresponding rates of emission;

(b) the concentration of carbon dioxide, oxygen, nitrogen and water vapor; and

(c) the total flue gas flow rate and temperature.

Representative samples of particulate matter being exhausted from the main stack shall be analyzed for total heavy metals content at approximately three-month intervals for the first year of operation and at a frequency to be determined in subsequent years.

A static ambient air quality monitoring program designed to assess levels of sulphur dustfall, hydrogen sulphide and total sulphation shall be provided and the number of stations shall be determined from Attachment II.

A continuous ambient air quality monitoring survey for sulphur dioxide and hydrogen sulphide shall be conducted at a frequency to be determined from Attachment II. The number of continuous monitoring stations which must be provided is also specified in Attachment II. Each station must be equipped with instruments for measuring both wind speed and direction on a continuous basis.

(4) Topography and Meteorology of the Oil Sands Area

The most dominating geological feature of the entire oil sands area is the presence of the Athabasca River. The geographical relationship between the river and the bituminous sands formation will inevitably result in the construction of several plants along the river valley and the influence of the river becomes apparent when analyzing the effects of plume overlapping. As the development of the area progresses northward, the Birch Mountains will become an important topographical concern in selecting the location and design of nearby plants.

Due to the prominence of the river and the high frequency of light winds, the potential for air pollution episodes appears imminent, especially during prolonged winter inversions which are common to the oil sands area. The winter conditions in the Fort McMurray area are very severe in that the Continental Arctic air mass dominates for extended periods of time. This type of weather results in very low ambient temperatures (-50° to -60° F), light winds (8 to 10 MPH), high frequencies of calm conditions (15 to 20%) and very stable atmospheric conditions characterized by temperature inversions. In contrast to the winter climate, the summer weather is quite different. Relatively unstable conditions predominate with higher winds and improved

atmospheric mixing. Nocturnal inversions are common but are very short in duration and do not pose any significant problem.

Recent environmental studies such as the INTEG report "An Environmental Study of the Athabasca Tar Sands", and a government task force report, "Climatological and Meteorological Research Needs for the Athabasca Tar Sands Area" all emphasize one main point, namely - the existing meteorological and climatological data for the oil sands region is not adequate and is not representative of the valley area where the pending development will occur. The Fort McMurray Airport is the only local synoptic weather station but this one location is not sufficient to supply data on a micro - or a meso - scale for areas north and south along the Athabasca River.

A summary of the research and field observations recommended by the Conservation and Utilization Committee Task Force is presented in Table III. In reviewing the contents of this table, it becomes very evident that a concerted effort must be made to collect and analyze the meteorological data to more effectively coordinate the development of the oil sands area. A research project with the magnitude of this one must be given an extremely urgent priority if the future growth of the oil extraction industry is to be compatible with the local environment.

(5) Conclusion

An enormously complex natural resource development is about to unfold in the Athabasca Oil Sands to supplement North America's increasing demands for energy and hydrocarbon feedstocks. Unless this development is coordinated to minimize the effects on the surrounding environment, the pending industrial expansion

could conceivably result in irreparable damage to a very sensitive portion of Alberta.

Alberta Environment has a basic responsibility of preserving the integrity of the oil sands ecosystem . Initial government environmental studies have been completed to assess the impact of present and future oil extraction operations, and industry as well, will be required to assess its total impact in the form of environmental impact surveys.

The use of ambient and source emission standards are a necessity to limit atmospheric contaminant discharges to levels not detrimental to the surrounding environment. Basic emission design parameters are a necessity for the control of air pollutants originating within oil extraction plants. To evaluate the performance of the various pollution control facilities, ambient and in-stack monitoring systems are an important extension of basic process control instrumentation.

Some local meteorological data is available for the immediate Fort McMurray area, but this is not representative of the remaining oil sands area. There is an urgent need for much more detailed meteorlogical and climatological research if the potential effects of the increasing atmospheric contaminants load are to be fully understood.

TABLE I

THE CLEAN AIR (MAXIMUM LEVELS) REGULATIONS (PART I)

MAXIMUM PERMISSIBLE AMBIENT CONCENTRATIONS

CONTAMINANT	TIME PERIOD	CONCENTRATION $\mu g/m^3$	CONCENTRATION PPMV
Sulphur Dioxide	Annual Arithmetic Mean	30	0.01
	24 - hour	150	0.06
	1 - hour	450	0.17
	1/2 - hour	525	0.20
Hydrogen Sulphide	24 - hour	4	0.003
	1 - hour	14	0.010
	1/2 - hour	17	0.012
Oxides of Nitrogen (as NO_2)	Annual Arithmetic Mean	60	0.03
	24 - hour	200	0.10
	1 - hour	400	0.20
Carbon Monoxide	8 - hour	6 mg/m^3	5
	1 - hour	15 mg/m^3	13
Total Oxidants	24 - hour	30	0.015
	1 - hour	100	0.05
Suspended Particulates	Annual Geometric Mean	60	--
	24 - hour	100	--

Total Dustfall (Making due allowance for normal background levels)

Residential & Recreational Areas	30 days	53 mg/100 cm^2	15 tons/$mile^2$
Commercial & Industrial Areas	30 days	158 mg/100 cm^2	45 tons/$mile^2$

TABLE II[1]

SULPHUR RECOVERY GUIDELINES

Inlet Rate to Plant (Long Tons of Sulphur per Day)	Sulphur Recovery Efficiency (Percent)
1000 - 4000	98.5
400 - 1000	97.0
100 - 400	95.0
10 - 100	93.5

TABLE III (2)

Summary of the Main Research Required and the Meteorological Observations Necessary to Solve the Major Identified Atmospheric Environmental Problems that will be caused by Extensive Development of the Athabasca Tar Sands

SCALE OF PHENOMENA	RESEARCH REQUIRED	OBSERVATIONS NECESSARY	APPLICATION
MICRO-SCALE Local scale up to distances of approximately 5 miles	- diffusion from single point sources - evaporation from tailings ponds - fog formation	- five valley floor stations continuously measuring temperature (wet and dry bulb), wind (speed and direction (amount and intensity) - 300-ft meteorological tower and fixed mini-sonde station - collection of fog samples	- details of individual plant design - stack heights, location of tailings ponds etc. - ambient SO_2 concentrations - odour problems
MESO-SCALE Regional scale up to distances of 100 miles	- three dimensional modelling of structure and flow in valley - drift, persistence and chemical reactions of fog - additive and/or synergistic effects of multiple sources	- station (equipped as above) near top of Birch Mountain - limited duration intensive field studies using mobile mini-sonde, aircraft and remote sensing techniques - in-plume measurements of SO_2 and oxidation products downwind of source	- regional planning-location of plants in relation to each other, location of townsites, etc. - inadvertent weather modification
SYNOPTIC SCALE Large scale up to distances of 2,000 miles	- long range transport of pollutants - chemical reactions in clear atmosphere and in precipitation formation - pollution sinks - forecasting pollution potential ("episode climatology")	- solar radiation and evaporation at two stations - upper air station near Fort McMurray - network of precipitation sampling stations within 200 miles of Fort McMurray. Accurate precipitation amounts and intensity at some stations	- disposition of pollutants - acidification of soils and water in surrounding region - meteorological control, frequency and forecasting of periods of high pollution potential - inadvertent weather and climate modification

ATTACHMENT 1 (1)

MAIN STACK GAS MONITORING

A. Continuous

All oil sands processing plants emitting more than 5 long tons of sulphur per day shall continuously monitor stack gases for sulphur dioxide concentration, volume flow rate and temperature.

B. Periodic

All oil sands processing plants shall be periodically sampled and measurements made for:

(1) Concentration of sulphur dioxide, oxides of nitrogen, particulates, oxygen, carbon dioxide, nitrogen and water vapor;
(2) Volume flow rate;
(3) Temperature.

These surveys shall be conducted according to the following frequency:

Maximum Allowable Sulphur Emission Rate*LTS/D	Number of Stack Surveys Per Year
120 - 149	8
90 - 119	7
60 - 89	6
30 - 59	5
15 - 29	4
10 - 14.9	3
5 - 9.9	2
1 - 4.9	1
Less than 1	As Required

*LTS/D - Long tons of sulphur emission per stream day.

ATTACHMENT II (1)

AMBIENT MONITORING

A. All oil sands processing plants shall be required to implement both continuous and static monitoring programs for the determination of sulphur dioxide and hydrogen sulphide according to the following schedule:

Maximum Allowable Sulphur Emission Rate *LTS/D	Number of Continuous Stations	Months per Year	Number of Static Stations
120 - 149	5	12	40
90 - 119	4	12	35
60 - 89	3	12	30
30 - 59	2	12	25
15 - 29	1	12	20
10 - 14.9	1	9	16
5 - 9.9	1	6	12
3 - 4.9	1	3	8
1 - 2.9	1	2	4
Less than 1	As Required	As Required	2

*LTS/D - Long tons sulphur emission per stream day.

B. All oil sands processing plants producing elemental sulphur shall establish a sulphur dustfall exposure cylinder network for the measurement of elemental sulphur according to the following schedule except as noted below the schedule:

Sulphur Production LTS/D	Number of Sulphur Dustfall Exposure Cylinders
Greater than 1000	12
100 - 1000	8
Less than 100	4

1. Those plants shipping their total sulphur production in liquid form are exempted from sulphur dustfall monitoring.
2. Those plants stockpiling but not shipping solid sulphur are permitted to reduce the number of sulphur dustfall stations to one half of that shown in the schedule provided that the minimum is not less than four.
3. Those plants exempted in part 2 above must expand their network to the full compliment at least three months prior to break up of the sulphur stockpile.

REFERENCES

(1) "Syncrude Criteria", Alberta Department of the Environment, January, 1973.

(2) "Climatological and Meteorological Research Needs for the Athabasca Tar Sands Area", Task Force Report, Conservation and UTilization Committee, 1974.

(3) INTEG, Intercontinental Engineering of Alberta, Ltd, "An Environmental Study of the Athabasca Tar Sands", Alberta Environment, 1973.

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